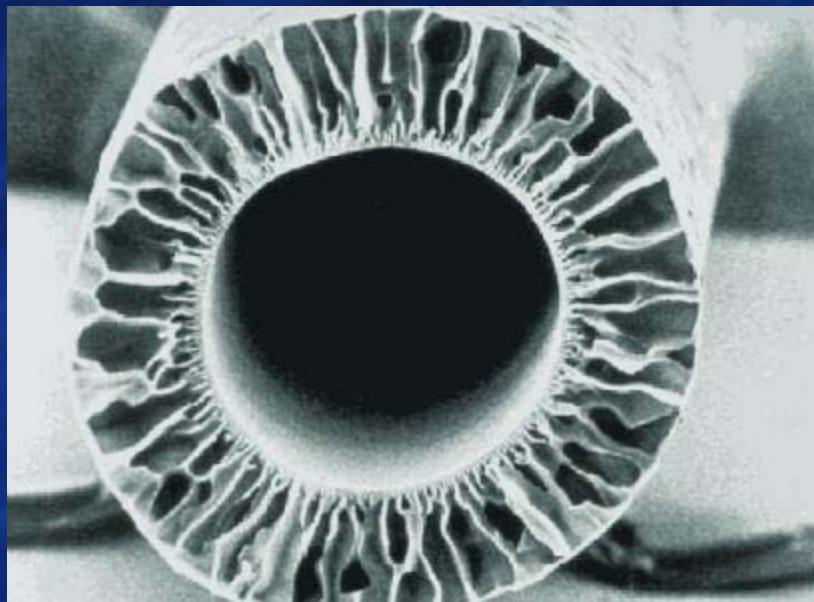


# **State-of-the-Art Filtration Technologies**



**Dr. Steven J. Duranceau, PE  
Boyle Engineering Corporation  
Orlando, Florida**

**BOYLE**

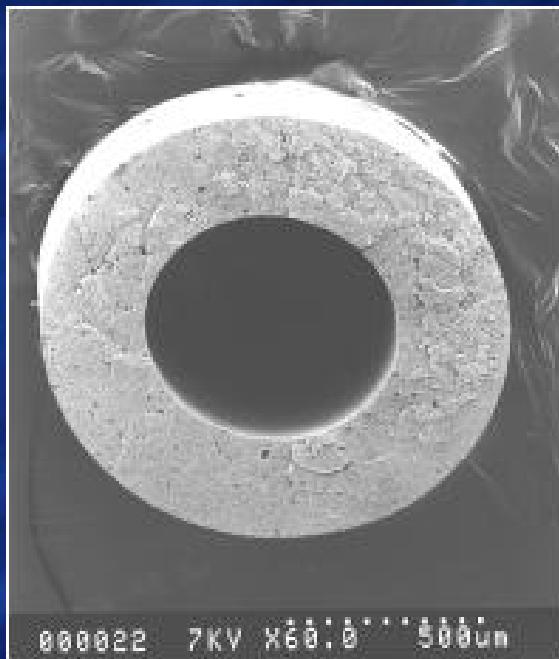
# Membrane Processes

- **Electrically-Driven**
  - Electrodialysis Reversal
- **Pressure-Driven**
  - Diffusion Controlled
    - Reverse Osmosis
    - Nanofiltration
  - Sieving-Controlled
    - Ultrafiltration
    - Microfiltration



BOYLE

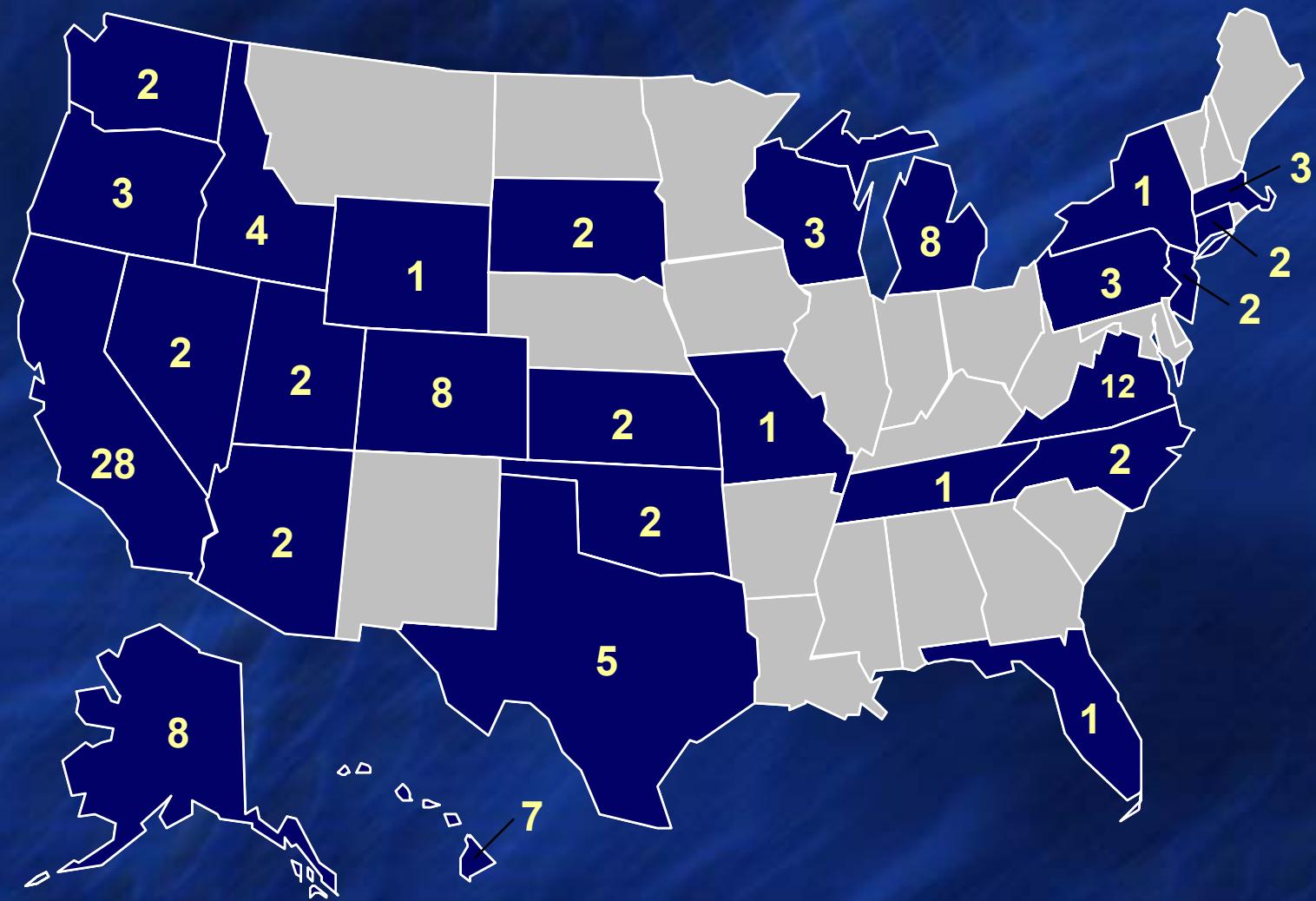
# **Microfiltration and Ultrafiltration: Leading the Way for Particle Removal Treatment**



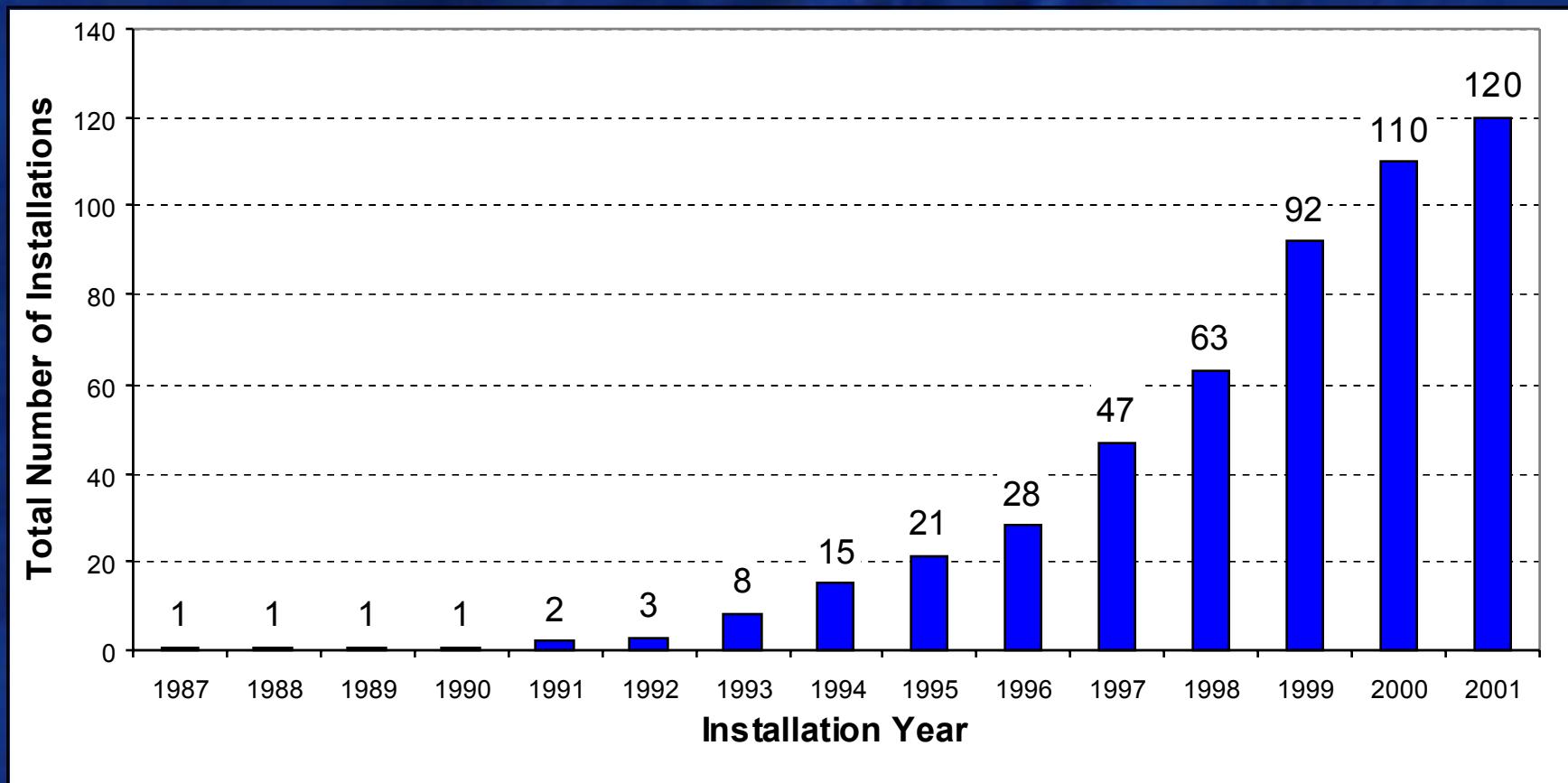
***Multiple Barrier  
Contaminant Approach  
with  
Membrane Processes  
Starts with MF and UF***

# MF/UF Plants in the United States

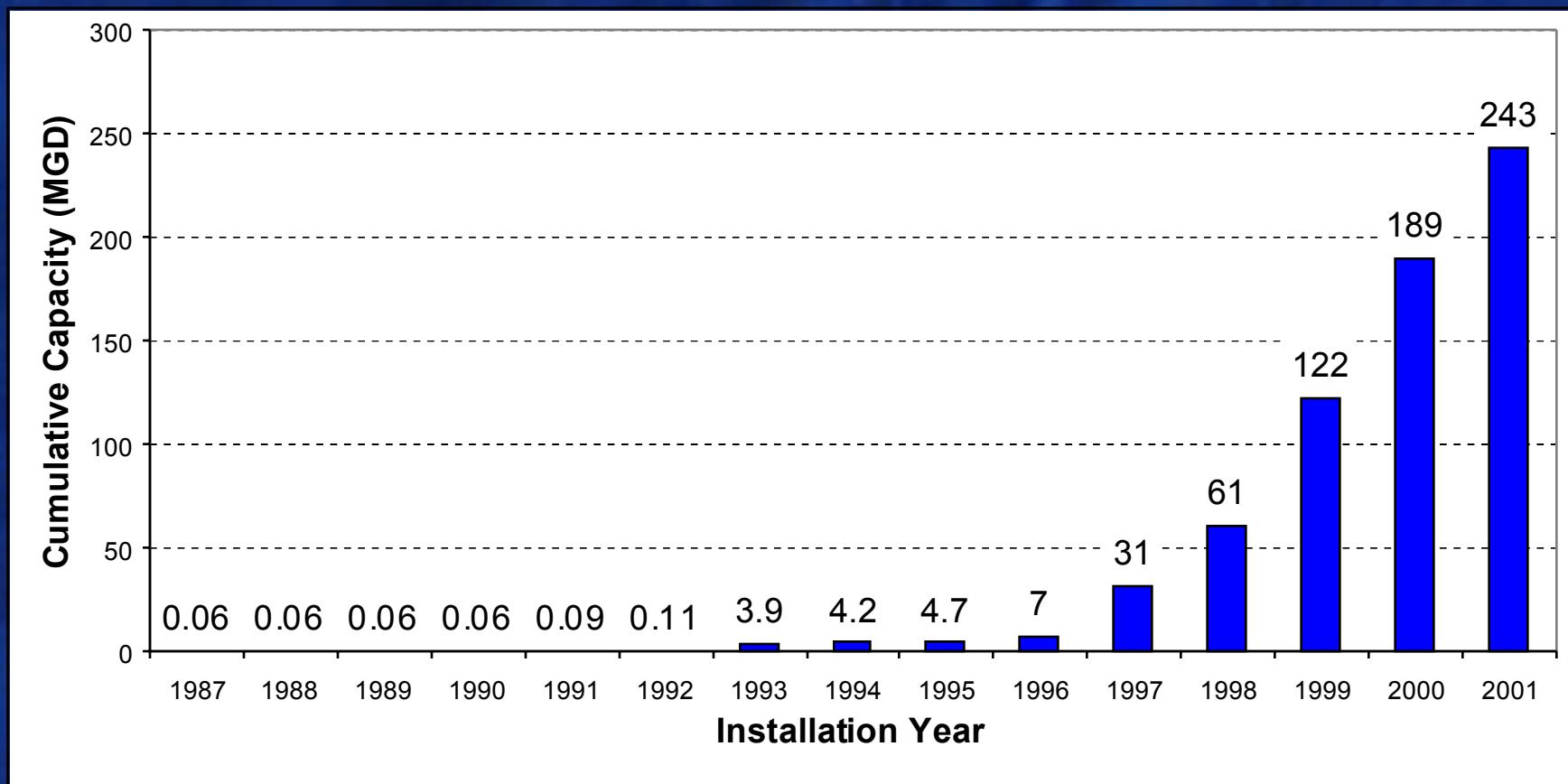
(Source: USEPA as of 2000)



# Cumulative Number of Membrane Filtration Installations

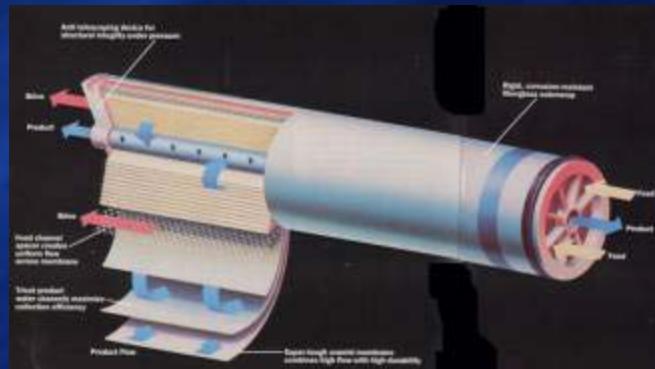
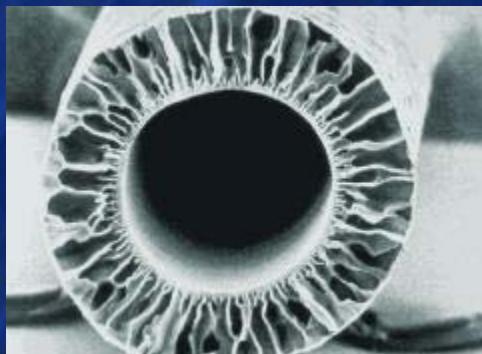


# Cumulative Membrane Filtration Capacity



# Characteristics of Membranes

- MF: 4 - 70 psi
- UF: 10 - 90 psi
- NF: 70 - 140 psi
- RO: 140 - 700 psi
- 0.1 - 3  $\mu$
- 0.01 - 0.1  $\mu$
- 200 - 400 daltons
- 50 - 200 daltons



# Effectiveness of Membranes

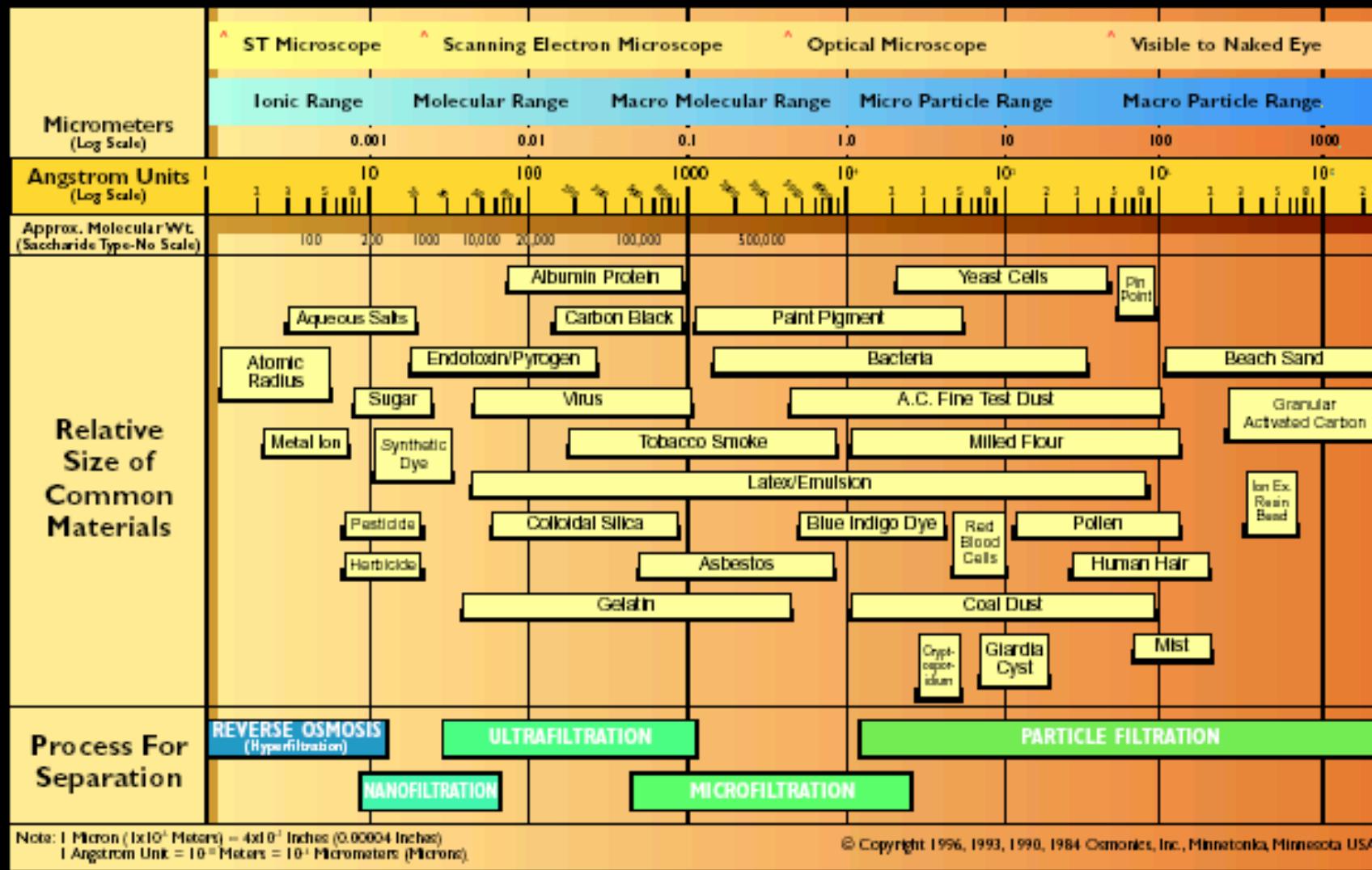
- MF       $\Leftrightarrow$  Particle, turbidity, bacteria, protozoa
- UF       $\Leftrightarrow$  MF plus virus removal, some TOC
- NF       $\Leftrightarrow$  UF plus color, most SOC<sub>s</sub>, IOC<sub>s</sub>, NPDOC (DBP precursor) removal
- RO       $\Leftrightarrow$  NF plus SOC<sub>s</sub> and salinity removal
- EDR       $\Leftrightarrow$  IOC<sub>s</sub> and salinity





**OSMONICS**

# The Filtration Spectrum



Osmonics, Inc.  
 Corporate Headquarters  
 8801 Clearwater Drive • Minneapolis, Minnesota 55343-8880 USA  
 Toll Free: 800/848-1750 Fax: 612/933-0141

Osmonics Asia/Pacific, Ltd.

Bangkok, Thailand Fax: 011-66-2-39-18183  
 Tokyo, Japan Fax: 011-81-48-622-6309

Osmonics Europa, S.A.

LeMee Sur Seine (Paris), France  
 Fax: 011-331-64-37-9211

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# SDWA Applications

## USA Regulation

## Membrane Process



USA Regulation	EDR	RO	NF	UF	MF
Surface Water Treatment Rule	No	Yes	Yes	Yes	Yes
Coliform Rule	No	Yes	Yes	Yes	Yes
Lead & Copper Rule	No	Yes	Yes	No	No
Inorganic Contaminants	Yes	Yes	Yes	No	No
Synthetic Organic Contaminants	No	Yes	Yes	No	No
Radium 226/228	Yes	Yes	Yes	No	No
Disinfection By-Products	No	Yes	Yes	No	No
GWDR	No	Yes	Yes	Yes	Yes
Arsenic	Yes	Yes	Yes	No	No
Sulfates	Yes	Yes	Yes	No	No

# Membrane Process Aesthetic Applications

Parameter	Membrane Process				
	EDR	RO	NF	UF	MF
Total Dissolved Solids	Yes	Yes	Yes	No	No
Hardness	Yes	Yes	Yes	No	No
Taste & Odor	No	Yes	Yes	No	No
Total Organic Carbon	No	Yes	Yes	No	No
Color	No	Yes	Yes	No	No
Fe & Mn	No	Yes	Yes	No	No

# Safe Drinking Water Act Enhanced Surface Water Treatment Rule

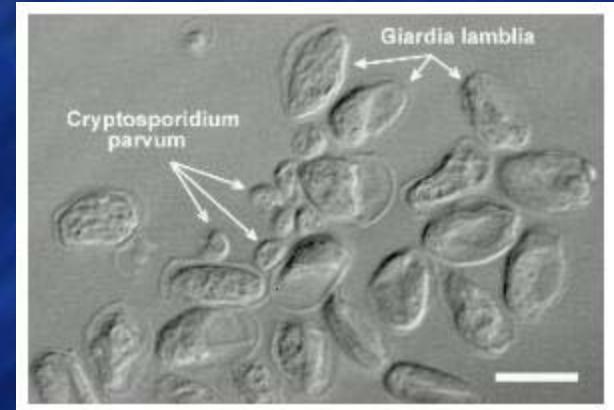
<u>Contaminant</u>	<u>Requirement</u>	<u>MF/UF Performance</u>
Turbidity	<0.3 NTU**	<0.1 NTU
<i>Giardia</i>	99.9% Removal	99.999+% Removal
<i>Cryptosporidium</i>	99% Removal	99.999+% Removal
Virus	99.99% Removal	99.99+% Removal
<i>Coliform</i>	None (95%)	99.99+% Removal

\*\* Not to exceed 1.0 NTU

# Emerging Water Quality Concerns

- **Emerging Pathogens**

- *Cryptosporidium*
- *Giardia*
- *Legionella*
- *Mycobacterium Aves complex*
- *Mircosporidia*
- *Enterovirus*



- **Endocrine Disruptors**

- **Pharmaceutically Active Chemicals**

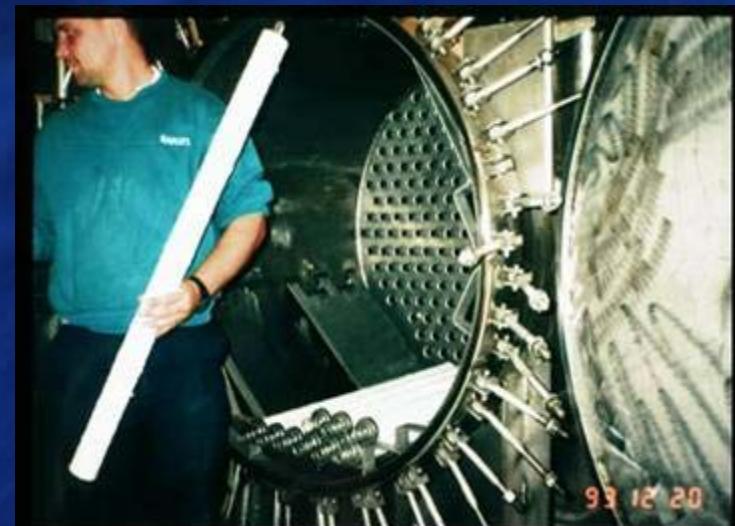
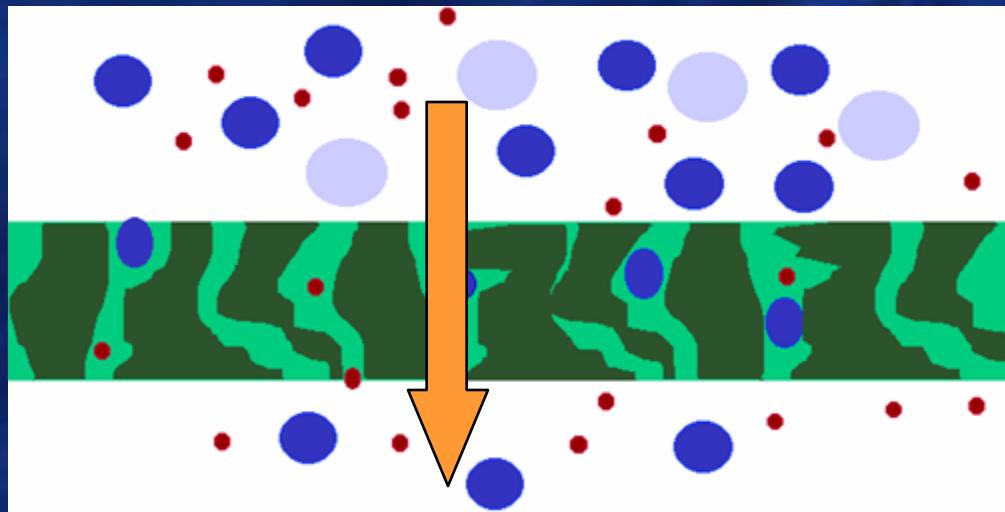
- **Terrorism Agents**

- Chemical [*cyanide*]
- Biochemical [*plague*]



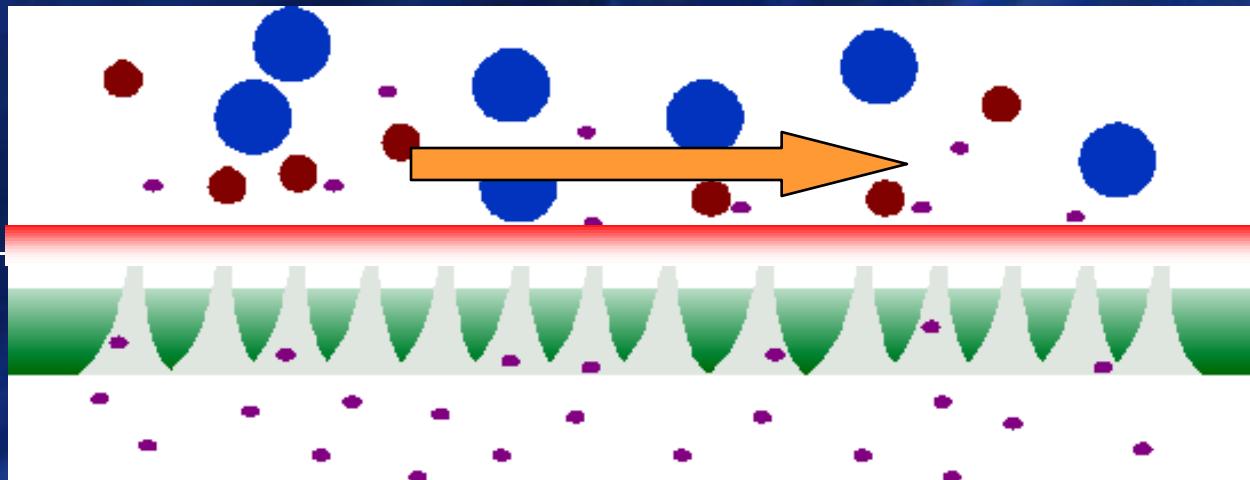
Giardia Cyst

# Conventional Filtration



# Membrane Filtration

Feed

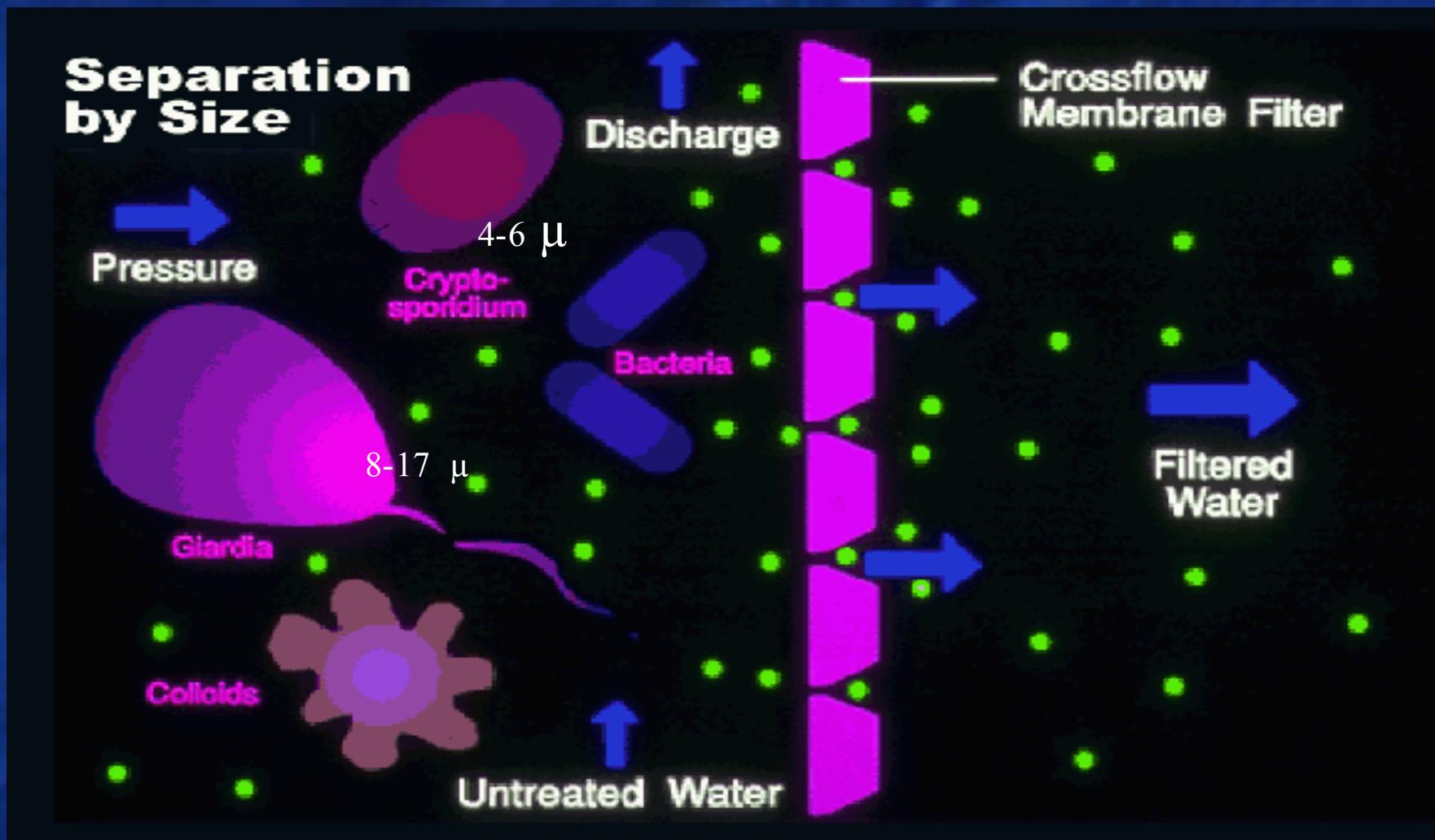


Permeate

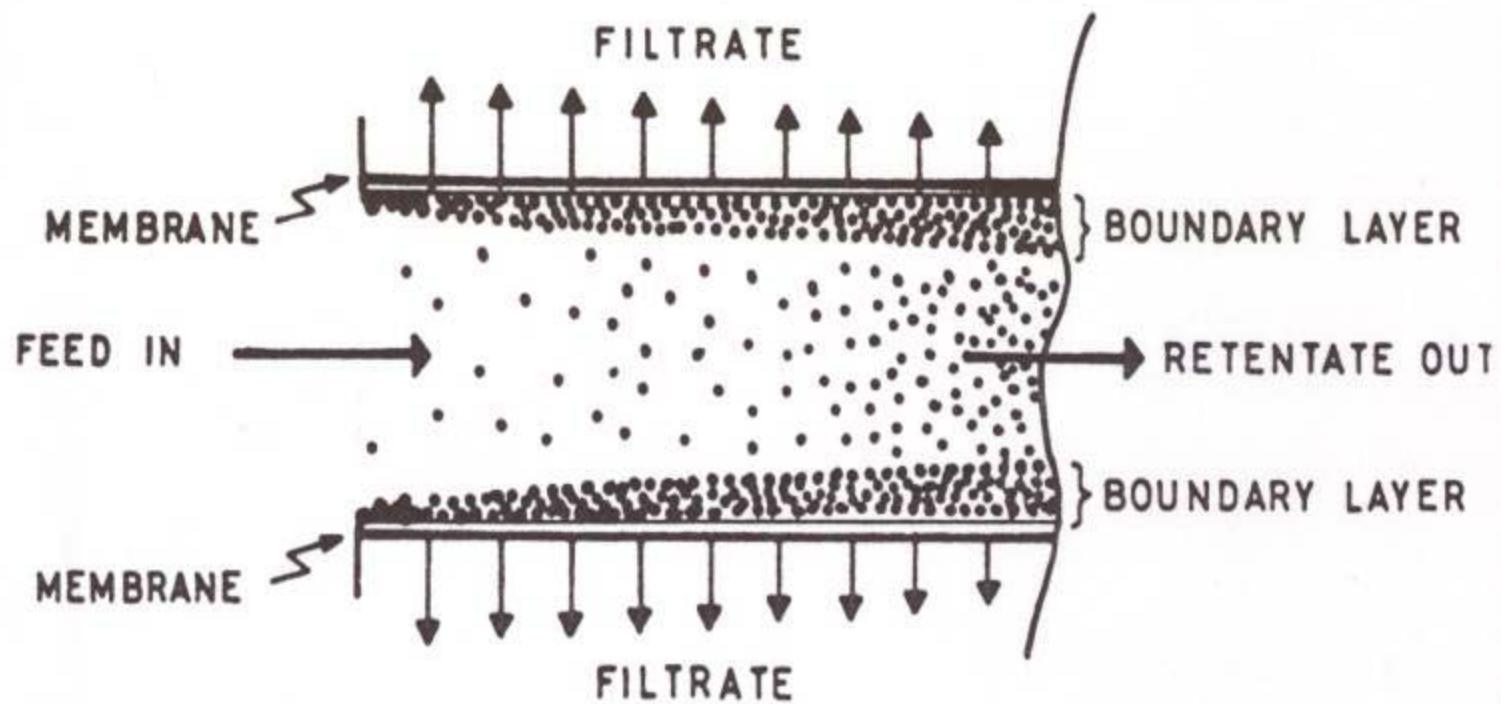
- No internal plugging
- Low membrane resistance
- High flux performance



# Separation by Size



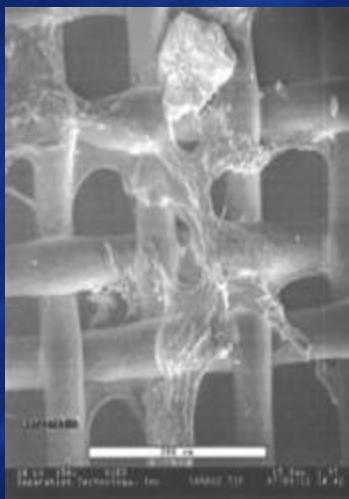
# Concentration Polarization



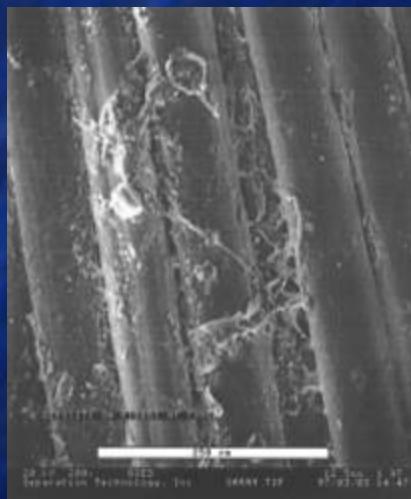
# Fouling: Four Mechanisms

- **DEPOSITION** of silt & suspended solids.
- **SCALING** of inorganic deposits formed due to concentration of sparingly soluble salts beyond the chemical solubility limit.
- **MICROBIOLOGICAL** growth entering or within element.
- **ORGANIC** interactions of natural or synthetic organics.

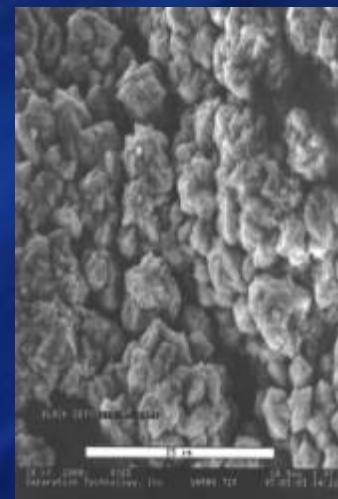
**DEPOSITION**



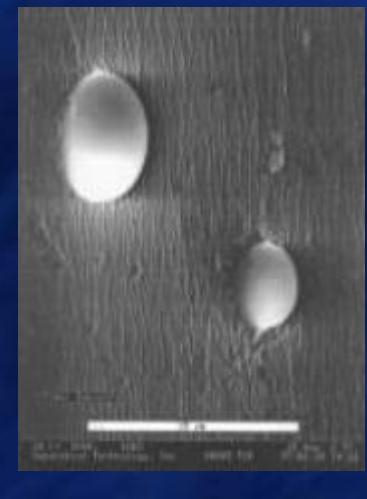
**MICROBIOLOGICAL**



**SCALING**



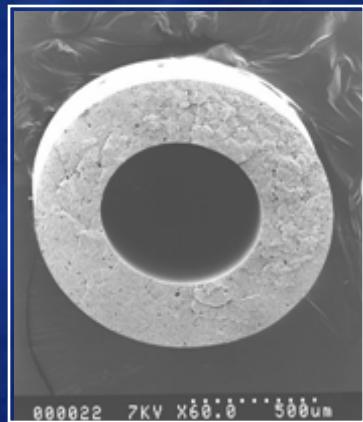
**ORGANIC**



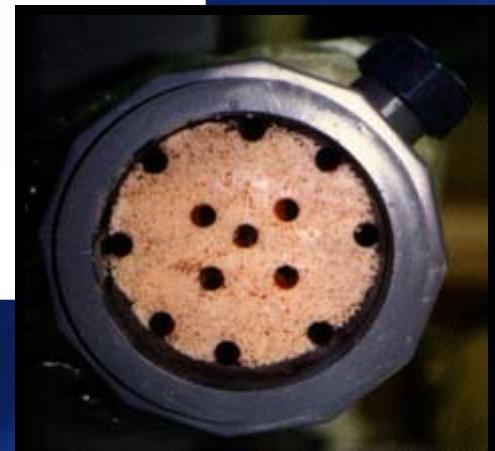
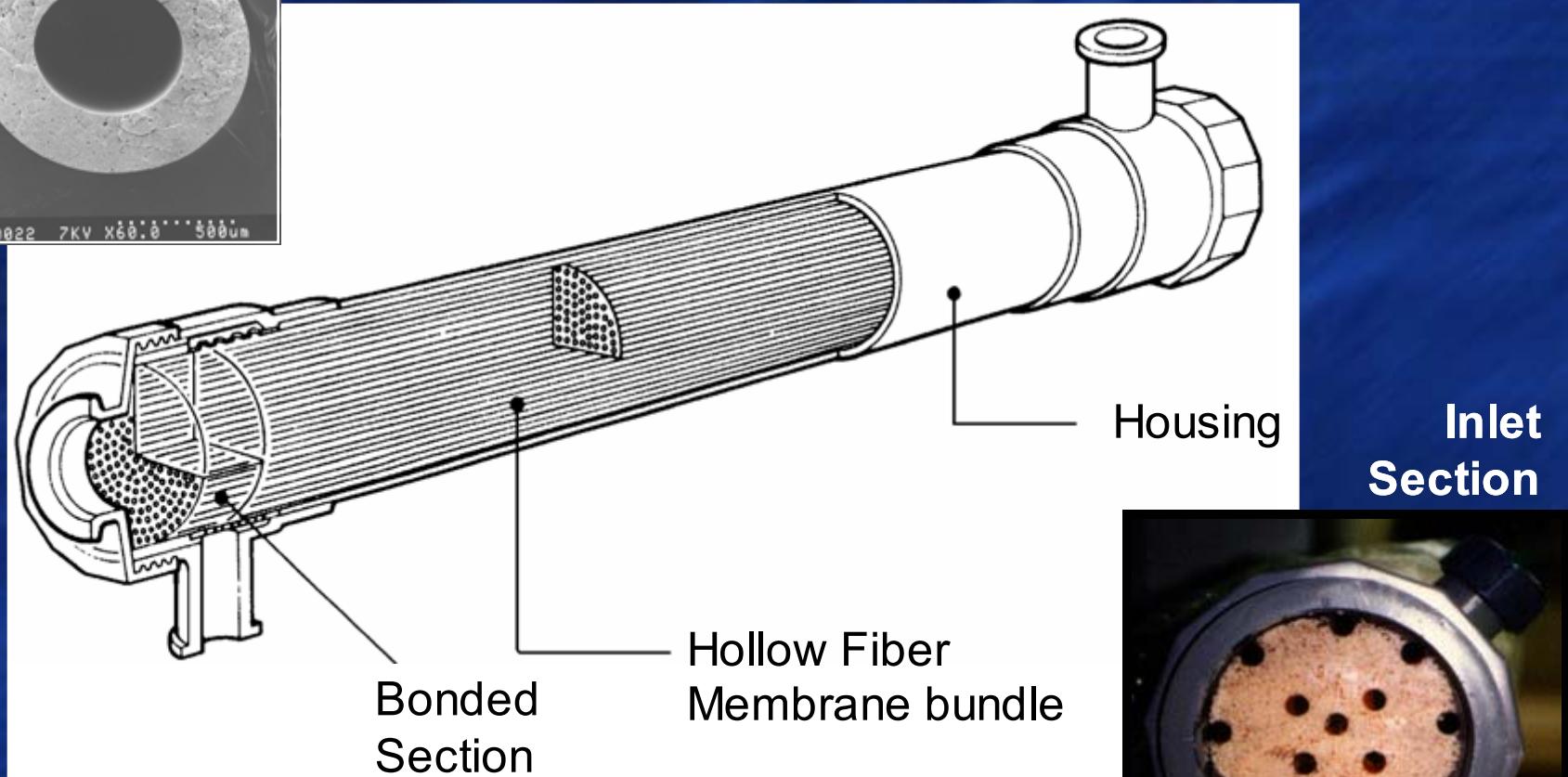
# MF and UF Modules

- **Vary in module type and size**
  - Immersed
  - Pressurized
- **Vary in membrane materials**
- **Pore size and capillary diameter may differ**
- **Position (horizontal versus vertical arrangements)**
- **Operating Principles**
  - Inside-out
  - Outside-in
- **Different backwash flush cycles**
  - Air/water
  - Water
  - Recycle





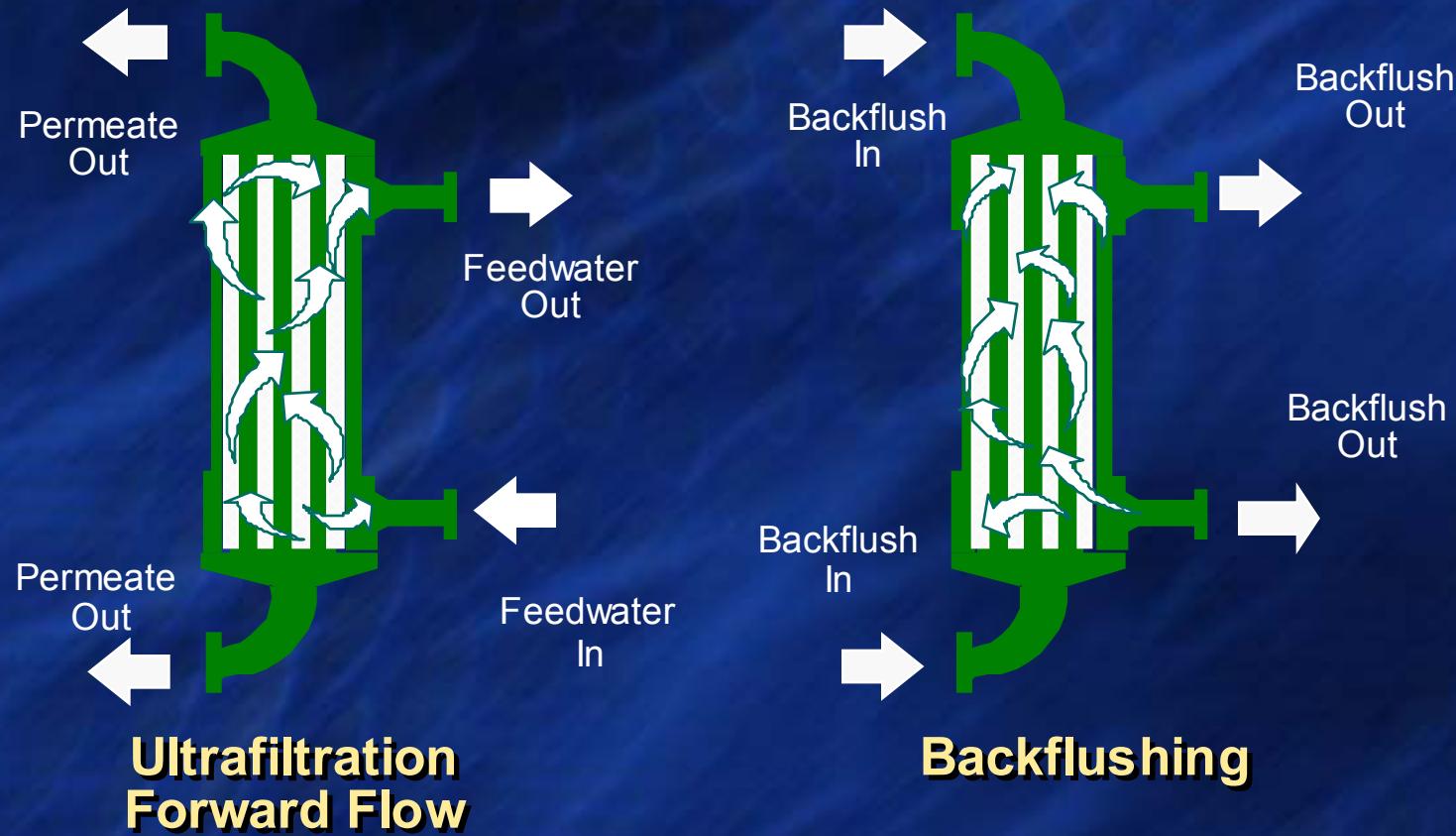
**Pall MF Fiber = 0.1 micron, PVDF (USV), Outside – In, Oxidant Resistance (Chlorine, Ozone & Chlorine Dioxide)**



# Hollow Fiber Operating Modes

**Backwash Techniques May Involve:**

- air and/or air/water
- internal recycle
- water backwash



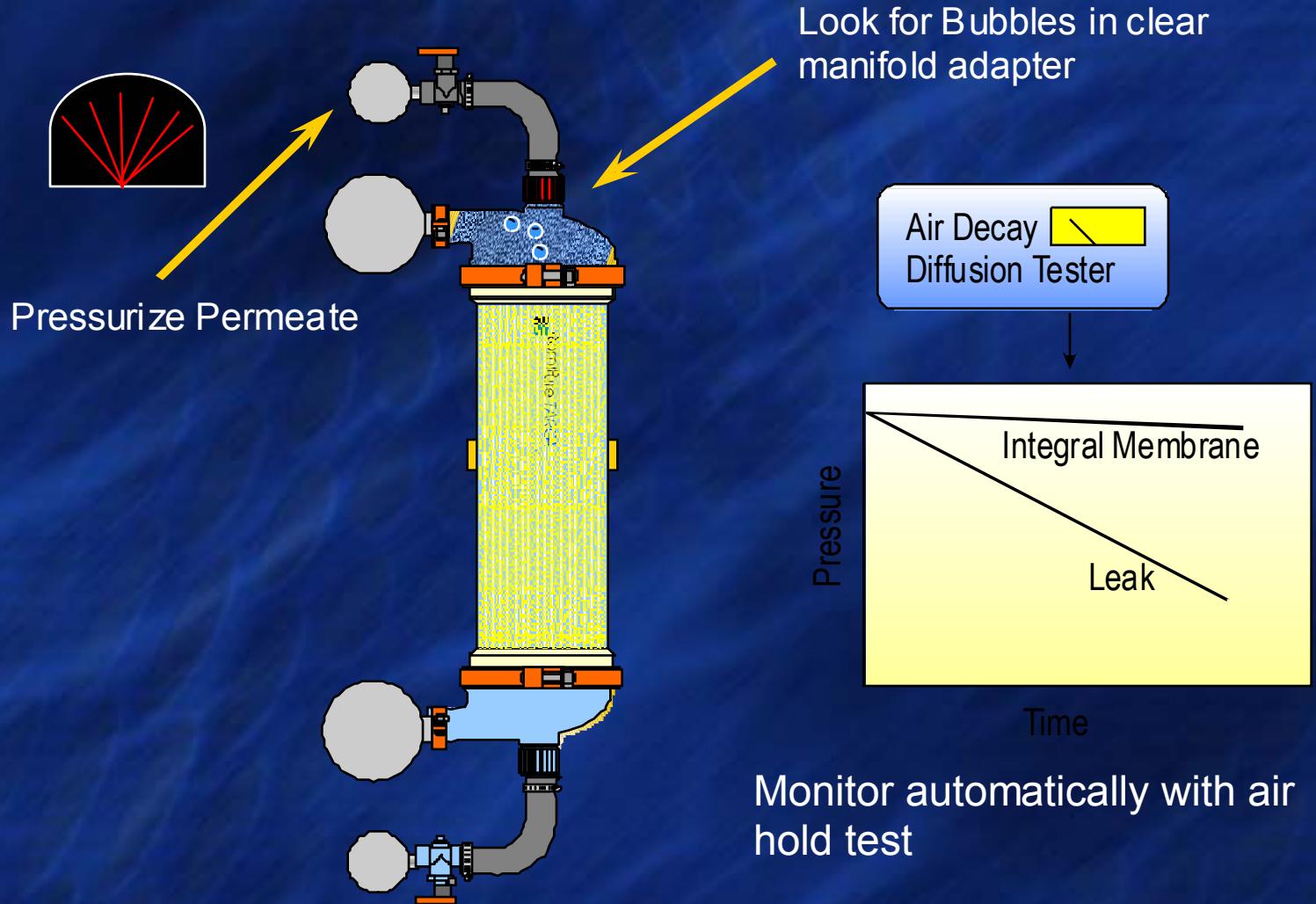
# Integrity Monitoring Techniques

- **Direct Methods**
  - **Pressure Hold Test**
    - (pressure decay)
  - **Diffusive Air Flow Test**
    - (flow sensing)
  - **Bubble Point Test**
    - (capillary pressure)
  - **Sonic Sensing Analysis**
    - (vibration sound)
- **Indirect Methods**
  - **Particle Counting / Monitoring**
  - **Turbidity Monitoring**

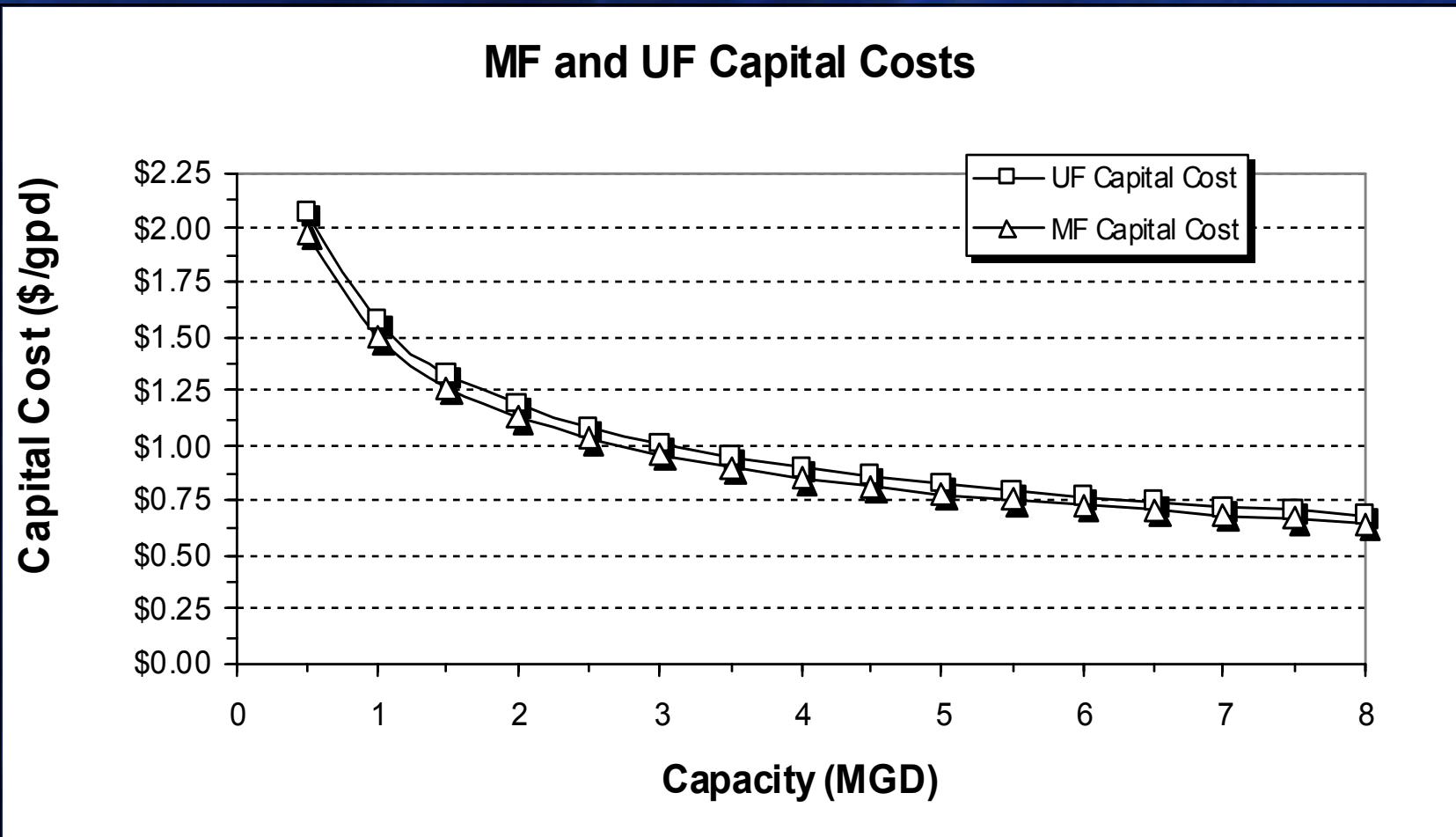


# Hollow Fiber Integrity Test

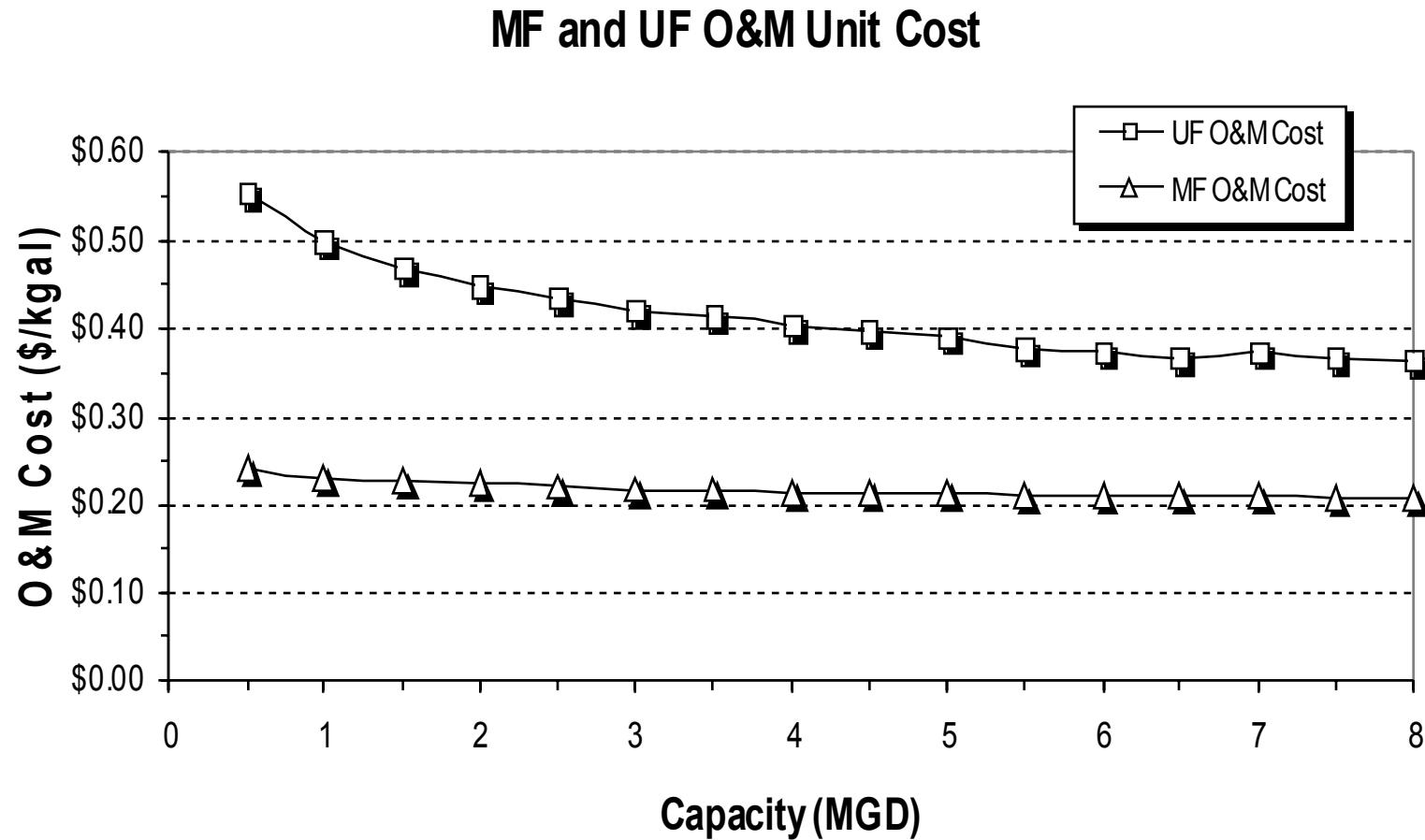
## *Visual and Pressure Tests*



# Example Capital Cost Curve



# Example O&M Cost Curve



# Appleton, Wisconsin (24 MGD)



# **Olivenhain MWD Encinitas, CA (25 MGD)**



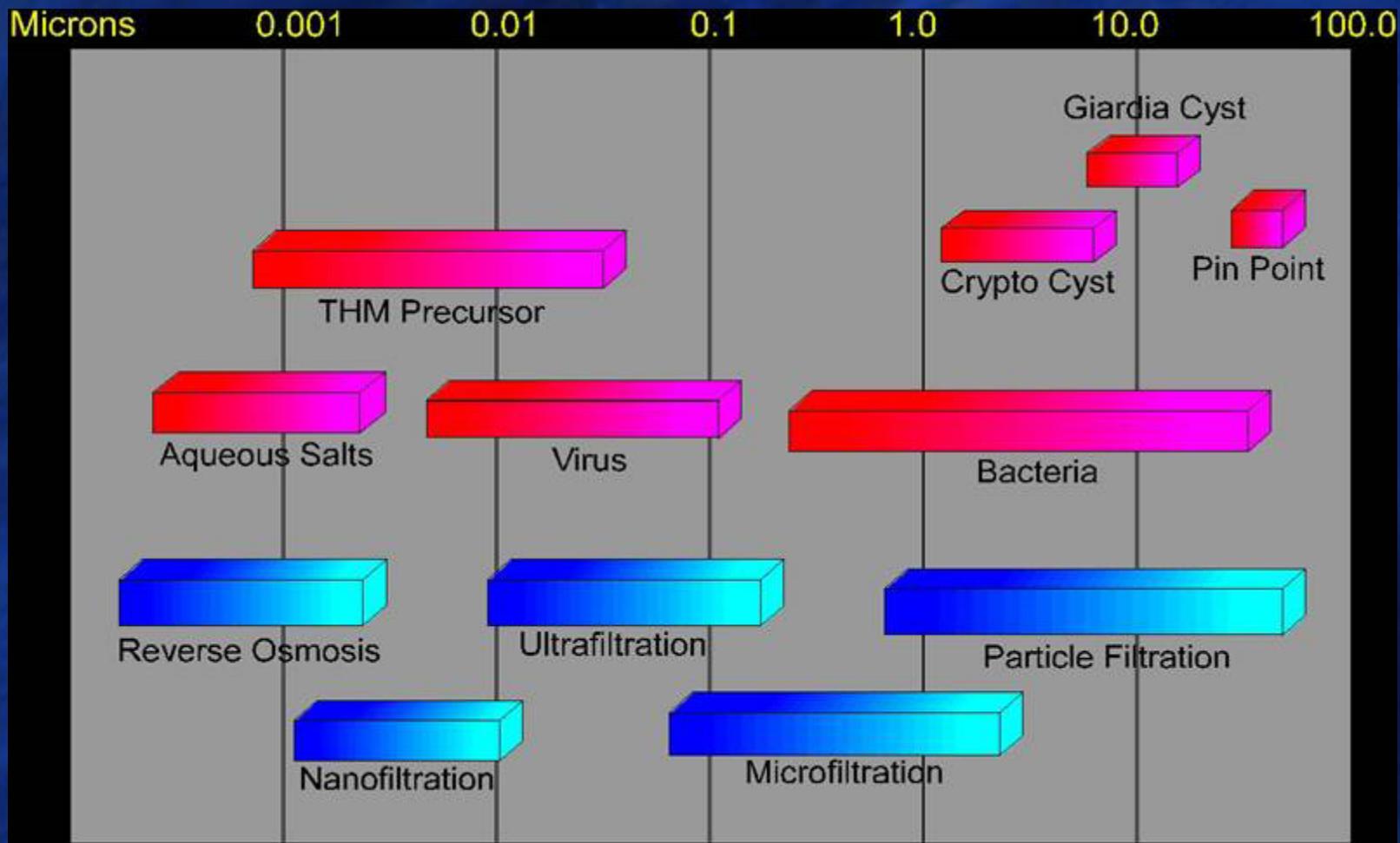
# San Patricio Municipal Water District, Texas (7.8 MGD)



# Marquette, MI (8 MGD)



# Summary: The Filtration Spectrum



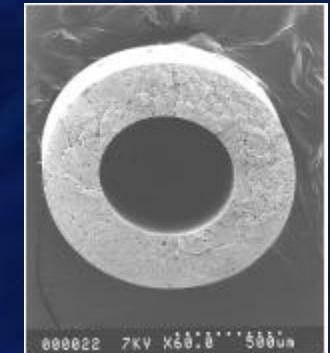
# What the Future Holds

- In 1995, ½ billion people in 31 countries suffered from water scarcity. By 2025, 3 billion people in 48 countries are expected to face water shortages

Source: Population Action International



- Improvements & New Technologies
  - Integrated Membrane Systems
  - Newer Membrane Materials
  - Imprinted Feed Channel Spacers
  - Pulse-Harmonics and Forward Osmosis
- Vulnerability Assessments
  - Membranes will take center stage



# Acknowledgements

- **AWWA Research Foundation**
- **Koch/Fluid Systems**
- **Zenon Environmental**
- **Pall Corporation**
- **GE Osmonics**





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